A PEST MANAGEMENT EVALUATION UPDATE FOR CALIFORNIA WALNUTS YEAR THREE

Request for Proposal (RFP No. 99-05)

SUBMITTED BY:

WALNUT MARKETING BOARD
DENNIS A. BALINT, EXECUTIVE DIRECTOR
1540 RIVER PARK DRIVE, SUITE 203
SACRAMENTO, CA 95815
(916) 922-5888 Fax (916) 923-2548
E-mail: walnut2@unlimited.net

March 9, 2000

Prepared for the California Department of Pesticide Regulation

DISCLAIMER

ACKNOWLEDGMENTS

The Walnut Marketing Board would like to acknowledge the following individuals for their contributions to the Pest Management Evaluation for California Walnuts:

Carolyn Pickel, Area UCIPM Advisor, Sacramento Valley, 142-A Garden Hwy., Yuba City, CA 95993, (530) 822-7515, cxpickel@ucdavis.edu

Walt Bentley, UCIPM Entomologist, Kearney Agr. Center, 9240 S. Riverbend Ave., Parlier, CA 93648, (209) 646-6527, walt@uckac.edu

Tim Prather, UCIPM Weed Ecologist, Kearney Agr. Center, 9240 S. Riverbend Ave., Parlier, CA 93648, (209) 646-6534, prather@uckac.edu

Terry Prichard, Extension Water Management Specialist, UCCE, 420 S. Wilson Way, Stockton, CA 95205, (209) 468-2086, tiprichard@ucdavis.edu

Rick Buchner, Farm Advisor, UCCE, 1754 Walnut St., Red Bluff, CA 96080, (530) 527-3101, rpbuchner@ucdavis.edu

Joe Grant, Farm Advisor, UCCE, 420 S. Wilson Way, Stockton, CA 95205, (209) 468-2085, jagrant@ucdavis.edu

Bill Olson, Farm Advisor, UCCE, 2279 Del Oro Ave., Suite B, Oroville, CA 95965, (530) 538-7201, wholson@ucdavis.edu

David Ramos, WMB Research Director, 2536 Corona Drive, Davis, CA 95616, (530) 756-0531, deramos@ucdavis.edu

Molly Espley, BIOS Program Coordinator, CAFF, P.O. Box 363, Davis, CA 95617, (530) 756-8518, bios@caff.org

This report was submitted in fulfillment of the project entitled *A Pest Management Evaluation Update for California Walnuts - Year Three* (RFP No. 99-05) by the Walnut Marketing Board under the sponsorship of the California Department of Pesticide Regulation. Work was completed as of March 9, 2000.

TABLE OF CONTENTS

LIST OF FIGURES

ABSTRACT

Growers are finding that more and more pesticides are required each year to keep codling moth population damage under control. This trend of increasing reliance on pesticides will continue unless reduced risk alternatives are developed for codling moth. Codling moth is the major insect pest and most of the organophosphates, carbamates and pyrethroids are applied to control codling moth in walnuts. Recent scientific evidence documents increased resistance of codling moth to Guthion. There is also increasing evidence that this resistance will carry over to some of the new soft chemicals like growth regulators. Developing and implementing a reduced risk management program using a multi-tactic approach based on mating disruption could result in a major reduction of pesticides in walnuts. Results from the Walnut Pest Management Alliance's project have shown some promising results from the first year demonstration. The most promising results have been with mating disruption in low codling population orchards. The second year demonstration project plans to demonstrate strategies to use mating disruption successfully in high codling moth populations. All of the other insect pests in walnuts can be controlled with native natural enemies in most years. Implementing a blight program will not greatly reduce the use of fungicides in wet years but will improve quality while minimizing sprays. Recent research with silicon penetrators applied at bud break showed promising results in 1999 even though it was a low rainfall year. Demonstrating new orchard floor management practices will reduce herbicide use, optimize irrigation and fertilization ensuring healthy trees and reducing the need for sprays on secondary insect and disease problems. As well as, reducing ground water contamination and pesticide run-off into surface water.

A PEST MANAGEMENT EVALUATION UPDATE FOR CALIFORNIA WALNUTS - YEAR THREE

PRODUCTION.

The Walnut Marketing Board is responsible for implementing the federal marketing order for California walnuts. California produces 99% of the walnuts grown in the United States and 38% of the world's production. From 1990-94, California's average production was 235,600 tons with a total crop value of approximately $313,600,000 (UCDANR, 1998). Bearing walnut acreage in California in 1997 totaled 177,206 acres with an additional 20,913 acres of non-bearing trees (NASS, 1997). The total cost to produce an acre of walnuts amounts to $3,022 (8). Over 40% of the California walnut crop is currently being exported. Thirty-five percent is marketed in shell increasing the need for non-stained shells with light colored kernels (UCDANR, 1998).

PRODUCTION REGIONS

The walnut industry developed in Southern California late in the 19th century. Now, the Sacramento and San Joaquin Valleys of California are the largest production areas with over 88% now being produced in the central valleys. Acreage is well distributed throughout these regions. The Coastal Valleys in the counties of Santa Barbara, Monterey and San Benito and areas in the Sierra Foothills account for the remaining 12%. Pest and disease pressures vary from region to region due to soil, climate, cultivars grown, presence of natural enemies, chemical resistance, pesticide application, availability of effective pest control measures and the pest management knowledge (UCDANR, 1998).

CULTURAL PRACTICES

Over 15 varieties of walnuts are grown in the state commercially, with numerous other cultivars being planted on a smaller scale. Selected cultivars are grafted onto rootstocks. The three rootstocks generally used in California are Northern California Black, Paradox hybrid, and English walnut. Both varieties and rootstocks vary in susceptibility to diseases, nematodes, and insect pests (UCDANR, 1998)

Walnuts are ideally suited to deep, well-drained, fine sandy loam to clay loam soils. However, as production areas on the West Side of the San Joaquin valley increased, salinity and boron toxicity have become more important in those areas. Walnuts will not produce adequate commercial crops without irrigation in most California growing areas. Flood, furrow, and sprinkler irrigation are predominant with drip and micro-sprinkler irrigation being used more often, especially in marginal soils. Non-cultivation of orchard soils with herbicide-treated tree rows is common. The increasing use of more efficient low-volume irrigation systems has increased the need for selective pre-emergence herbicide use in drip, micro-sprinkler, and sprinkler-irrigated orchards. Mechanized winter pruning is practiced and well suited to these sod orchard floor techniques with drip, micro, and sprinkler irrigation. A smooth orchard floor is necessary to facilitate harvest of walnuts that are shaken to the ground, swept into a windrow, and picked up with pickup machines. Some orchards are disked and rolled before harvest to insure a smooth, firm surface for harvest.

Most walnuts in California receive annual applications of nitrogen. Generally this is applied in the fall and early winter in the form of commercial fertilizer, although manure and leguminous cover crops are used in some cases. Zinc deficiency is also a problem in certain areas and is corrected by foliar applications of zinc compounds in the spring (UCDANR, 1998).

INSECT/MITE CONTROL

Codling Moth, *Cydia pomonella*

Codling moth is the key pest of walnuts and is the most economically important insect pest statewide and must be controlled in many early-blooming varieties. Approximately 60% of the acreage planted in California is susceptible to damage from codling moth and require from one to three treatments every year preventing serious economic damage. There are indications that codling moth is adapting to more tolerant cultivars increasing the percentage of susceptible acreage. Recent scientific evidence documents increased resistance of codling moth to Guthion. There is also increasing evidence that this resistance will carry over to pyrethroids and some of the new soft chemicals like growth regulators.

Codling moth larvae damage nuts by boring into nuts and destroying the kernels, rendering them worthless for commercial use. Codling moth overwinter as prepupae on the tree or in the soil around the base of the tree. In the early spring, adults emerge from over-wintering larvae, lay eggs giving rise to larvae that enter developing nutlets. Later generations either bore directly into the nut or enter the nut at the stem end after the hull hardens. Adult codling moths are about ½ inch long, gray in color with a prominent copper spot on the end of the forewings. Codling moth larvae are whitish to pink in color with mature larvae being about 3/4 inch long. There are usually three generations per year in the central valley of California, but a partial fourth generation may develop in warmer than normal years (UCIPM, 1987). In addition to direct crop loss of infested nuts, growers suffer increased penalties as the percent infestation rises because of elevated sorting costs. Codling moth infested nuts act as a food bridge for navel orangeworm and allows infestations to build up inside the orchard. If left uncontrolled, damage can exceed 40%. One of the demonstration blocks in 1999, using multiple applications of reduced risk practices, had as high as 10% damage at harvest.

Monitoring: Codling moth is monitored with pheromone traps that are utilized to assess population levels and calculate degree-days for timing treatments. Dropped nuts and canopy counts show close correlation to damage at harvest in the first year of the demonstration project. However, the common practice of using previous years grade sheets in making treatment decisions (UCPMG, 1998) was not an effective predictor of population levels in the demonstration project.

Chemical Control

Approximately 60 percent of walnuts in California are treated from 1 to 3 times (average 2 times) during the growing season for codling moth (CDPR, 1995). The Pesticide Use Database compiled by the Department of Pesticide regulation (DPR) from pesticide use reporting (PUR) shows an increase in FQPA risk insecticides applied to walnuts. Summaries of organophosphates, carbamates, and pyrethroids use in walnuts on a treated acre from 1990 through 1998. Since codling moth is the major insect pest, most organophosphates, carbamates and pyrethroids are applied to control codling moth in walnuts. Organophosphates use shown in Figure 1 has increased from 1.5 lbs. per acre in 1990 to around 2.0 lbs. per acre in the late nineties. The most carbamates (Figure 2) was used in 1995 however, as the use of pyrethroids increase (Figure 3) the carbamates use has decreased. Pyrethroid use saw a large increase in 1993. The largest pyrethroid use was in 1996, the year after the 1995 bad "worm" year in walnuts.

Azinphos-methyl - 21 days PHI. An organophosphate applied, usually once postbloom by ground at an average rate of 2 lb. a.i. per acre (CDPR, 1995). Some levels of codling moth resistance have recently been documented in walnuts in California (VanSteenwyk, 1998). This is still a valuable material in spite of pockets of resistance because the long residual covers the long codling moth hatch. Recent research shows that beneficials tolerate this material.

Chlorpyrifos - 14 day PHI. An organophosphate used primarily for codling moth. Applied by ground at the rate of 1.75 to 2.0 lb. a.i. per acre (CDPR, 1995). Recent data indicate that azinphos-methyl resistant codling moth may exhibit negatively correlated cross-resistance with chlorpyrifos, making this a valuable material in managing organophosphate resistance in walnuts (VanSteenwyk, 1998). It has a short residual and does not cover the entire egg hatch period. Because of its short residue it is relatively less harmful to beneficials. Chlorpyrifos also controls walnut aphid, soft scales, and walnut husk fly if properly timed (UCPMG, 1998).

Esfenvalerate - 21 day PHI. Applied postbloom by ground at .05 lb. a.i. per acre (CDPR, 1995). This material is very disruptive to the biological control of mites and should only be used late in the growing season. Also used for navel orangeworm and walnut husk fly (UCPMG, 1998).

Permethrin - 1 day PHI. A pyrethroid applied postbloom by ground at the rate of .25 lb. a.i. per acre (CDPR, 1995). Extremely disruptive to biological control of mites and because of this problem is not used in the San Joaquin Valley. Recent research has shown that pryrethorids will not control guthion resistant codling moths. Should only be used late in the season to preserve natural enemies early in the season (UCPMG, 1998).

Tebufenozide - 30 day PHI. Insect growth regulator applied postbloom once or more by ground and air at the rate of .25 lb. a.i. per acre (CDPR, 1995). This is a soft chemical, which can be integrated into a reduced risk program. The need for good spray coverage and big trees limits the utility of this material. Recent research has shown that there is cross-resistance with organophosphate. It will be an important material to integrate into an IPM program but in the long term walnut growers cannot rely on it as the sole reduced risk control program. We would expect to see an increase in use of this material as walnut growers adopt reduced-risk practices.

Diflubenzuron - 28 day PHI. Insect growth regulator applied postbloom one or more times by ground at the rate of .25 lb. a.i. per acre (CDPR, 1995). A soft chemical material used with a caution, since it is hard on hymenopterous parasitoids. May cause aphid outbreaks, but is not common. The need for good coverage and big trees limits the utility of this material. This material cannot be used with *Trichogramma* inundative release or importation of natural enemies.

Phosmet - 14 day PHI. An organophosphate registered for use on walnuts in 1996. The use rate is 2.1 to 4.2 lb. a.i. per acre (CDPR, 1995). Less disruptive to beneficial mites and arthropods than some other organophosphates. Used in walnut orchards where proximity to nonagricultural activity and native wildlife habitat necessitates use of a pesticide with minimal impact on non-target organisms. Late season applications will control walnut husk fly and navel orangeworm if properly timed.

Methyl-parathion - PHI 14 days. Received a SLN for walnuts in California in 1997 and is included in the organophosphate summary in Figure 1. Applied postbloom by ground at the rate of 1.5 to 2.0 lb. a.i. per acre. Maximum of 8 lb. a.i. per season. Recent data indicate that azinphos-methyl resistant codling moth may exhibit negatively correlated cross-resistance with methyl-parathion, making this a valuable material in managing organophosphate resistance in walnuts (VanSteenwyk, 1998). It is anticipated this material will be applied to significant acreage in response to the development of azinphos-methyl resistant codling moth, particularly in the southern San Joaquin Valley.

Diazinon (see walnut aphid) and **Methidathion** (see scale) will also control codling moth.

Alternatives

Codling Moth Granulosis Virus has been shown to be somewhat effective. It must be eaten by larvae and from 9 to 12 applications are needed each year to cover the long generation time (UCIPM,1998). Timing treatments is extremely difficult because irrigation scheduling prevents growers from getting into orchards in a timely matter. Also, because walnut trees are large, it is difficult to achieve adequate spray coverage. It is not currently available in the United States.

Bacillus thuringiensis (BT) has recently been tried on walnuts for codling moth control. Since codling moth can feed outside walnuts for 7 days it may have enough exposure to the stomach poison for control. Recent research trails has shown 9 applications will provide Class 1 nuts, which is less than 5% damage (Pickel, 1998). Walnut growers will not easily adopt multiple applications but this material may be integrated into a management program to supplement mating disruption or biological control. This material will also be applied for red-humped caterpillars. Summary of BT use in walnut by year is shown in Figure 4. BT use in walnuts has shown a slow increase, with the highest use in 1994 and 1998. We would expect to see an increase in BT use as reduced-risk practices are adopted.

Trichogramma platneri, a codling moth egg parasite, has reduced codling moth damage from 50%-70% when 12 weekly releases of 150,000-200,000 per acre per week are made into each tree in low to moderate population situations (UCPMG, 1998). This level of control is not adequate to prevent a buildup over time and economic damage in most walnut orchards in the state. This method maybe integrated with mating disruption or soft chemical programs. This method would be more quickly adopted if the cost per acre went down.

Research conducted on walnuts in the early '90s showed that mating disruption could be an effective but expensive alternative. More recent adoption and improvement in technology for pears and apples and the current regulatory environment and resistance problems allows for changes in development of reduced-risk practices that will be more readily adopted by walnut growers. The mating disruption mechanism is not fully understood, however with the loss of many cheap effective organophosphates, mating disruption programs needs to be researched in walnuts so it can be integrated into codling moth control programs. Pheromones equipped with a dispenser are commercially available and can be used in the walnut PMA field demonstration programs, however, sprayable and other forms of pheromone technology need to be explored.

Cultural Control Practices

Cultural controls such as banding and trapping pupating larvae have been tried for centuries. Since there are so many pupation sites on a tree the bands will only attract a proportion of the population. Destroying infested dropped nuts has also been tried but with limited success (UCIPM, 1987). This technique could be recommended to reduce populations aiding control with alternative practices.

Biological Controls.

Although over 250 biological control organisms have been shown to attack codling moth, none are capable of keeping populations below that which causes economic damage.

A key practice for implementation of reduced-risk systems in walnuts is increasing the reliability of biological control of codling moth by developing techniques for and releasing *Trichogramma,* and importing codling moth parasites from Kazakhstan. Dr. Nick Mills, UC Berkeley (Mills, 1998), is conducting this research currently being funded by the walnut board,

Other Issues.

Exports to Japan and other countries may be a problem. Most of the export criteria are based on the present chemical management system. They may be reluctant to let reduced risk nuts to be exported if the receiving country perceives a threat that infested nuts will be exported.

Navel Orangeworm, ***Amyelois transitella***

This scavenger insect attacks a wide range of walnut varieties; feeding directly on the kernel inside the nut. It not only destroys kernels, but also may be associated with fungi responsible for aflatoxin. Navel orangeworm larvae cannot enter sound nuts so damage occurs after hullsplit and before harvest. Navel orangeworm overwinters as larvae inside mummy nuts left on the tree and in trash nuts left on the ground. Silver gray moths of the overwintered brood emerge in spring and lay eggs on nuts damaged by codling moth or blight, which act as a food bridge for this generation. After hatching, white neonate larvae of the first generation enter nuts damaged by codling moth or walnut blight, making codling moth and blight control extremely important. Larvae mature inside nuts producing large amounts of frass and webbing. Mature larvae are white or pinkish and may reach 5/8 inch in length. After hullsplit, adults lay eggs directly on the hull of sound nuts and the tiny larvae enter nuts through the soft tissue at the stem end and do not emerge until they are adults (UCPMG, 1998). There are 3 to 4 generations per year. Twenty-percent damage is not uncommon in late harvested orchards.

Monitoring: Egg traps are used to monitor navel orangeworm (NOW) and give some indication which blocks should be harvested earliest (UCIPM, 1987). Egg traps do not work well under high population pressure or high blight years.

Chemical Controls

Chemicals are an important part of a 3-step program for managing navel orangeworm in walnuts and provide 50-70 percent reduction if used correctly (UCIPM, 1987).

Azinphos-methyl - 21-day PHI. Applied postbloom by ground at an average rate of 2 lb. a.i. per acre (CDPR, 1995).

Esfenvalerate - 21 days PHI. Applied postbloom by ground at .05 lb. a.i. per acre (CDPR, 1995). Can be used close to harvest. This material is very disruptive to the biological control of mites and should only be used late in the growing season. Also used for codling moth and walnut husk fly (UCPMG, 1998).

Carbaryl - 0 days PHI. Applied postbloom by ground at 4 lb. a.i. per acre (CDPR, 1995). Best used late in the season because it causes mite buildup (UCPMG, 1998).

Phosmet (see codling moth) will also reduce navel orangeworm.

Alternatives

Sanitation and early harvest are currently widely used as part of a navel orangeworm management program in walnuts.

Cultural Control Practices

Control codling moth and walnut blight to eliminate these sources for 1st generation larvae and preclude an early buildup inside the orchard (UCIPM, 1987). Shake mummy nuts from trees and flail all sound nuts on the orchard floor to reduce overwintering populations. In addition, good sanitation is a must around hullers, bins, dryers, and buildings where nuts have been handled. Early and rapid harvest, including use of Ethephon to promote early harvest, prompt drying, and fumigating will all help reduce damage by NOW (UCIPM, 1987).
Sunburn and Boron toxicity found on the west side of the valley can also serve as hosts for build up of navel orangeworm. Optimizing irrigation by soil moisture monitoring helps prevent sunburned nuts.

Biological Controls

Two introduced wasps, *Goniozus legneri and Pentalitomastix plethoricus,* are established in many areas but are not effective in controlling NOW in walnuts (UCPMG, 1998).

Walnut Husk Fly, *Rhagoletis completa*

Walnut husk fly is a direct pest of walnuts. This fly attacks all varieties and is most damaging on mid and late season walnuts, especially those marketed in shell. Larvae feeding in the husk cause darkening of the shell, and shrivel and mold on the kernels. Adult husk flies are about the size of a housefly and very colorful with characteristic bands on the wings. They overwinter as pupae in the soil and emerge in mid summer. Females deposit a clutch of eggs just below the surface of the husk. White maggots emerge from the eggs and feed in the husk causing the husk to become mushy and black. Mature larvae are yellow about 1/4 inch long. When mature, they drop to the ground, bore into the soil and pupate. There is one generation per year (UCIPM, 1987). Fifty percent damage can occur in some varieties if not controlled.

Monitoring: Adult flies are monitored using yellow sticky traps to detect emergence. Examine for eggs to determine when egg laying begins (UCIPM, 1987).

Chemical Control

If bait is combined with insecticide, alternate row treatments are effective, thus reducing the pesticide needed by one-half. Eighty percent of the acreage treated for husk flies uses bait plus insecticide combination (CDPR, 1995). Bait can also be added to late season codling moth treatments when damage is expected through monitoring. Treatments are timed 7 days after pregnant females are found on traps, which correspond to egg laying (Olson, 1997).

Malathion - PHI 1 day. An organophosphate applied postbloom by ground or air in July or August at the rate of 1.75 lb. a.i. per acre (CDPR, 1995). Has been implicated in inducing mite buildups. Malathion used primarily for walnut husk fly is included in Figure 1.

Esfenvalerate - PHI 21 days. Applied postbloom by ground or air in July or August at the rate of .05 lb. a.i. per acre (CDPR, 1995). Can increase mite problems (UCPMG, 1998).

Phosmet and **Chlorpyrifos** (see codling moth) will also control walnut husk fly.

Alternatives

To minimize sprays in husk fly infested areas, growers need to monitor females and spray when eggs are found. Spot treatments with malathion and bait will be the most efficacious and least disruptive control program. These spot treatments would minimize the amount of pesticide and would be less harmful to beneficials.

Biological Control

A number of parasites have been introduced. At least one species has been recovered in small numbers, but has no impact on husk fly numbers. Past research by Dr. Ken Hagen was unable to find successful biological control agents. Predaceous ground beetles could possibly have an impact.

Cultural Controls

Many cultural controls have been thought up, but there is little evidence to support their success. Cultural practices to increase ground predation may be helpful. Proper irrigation to reduce wet areas in the orchard that serve as hot spots may also be helpful.

<u>Aphids</u>:
<u>Walnut Aphid</u>, *Chromaphis juglandicola*
<u>Dusky-veined Aphid</u>, *Callaphis juglandis*

These occasional pests frequently build up to numbers adequate to cause stress on new leaf and walnut growth by extracting large amounts of leaf fluids. The walnut aphid was historically a major pest in walnuts until the successful introduction of a wasp parasite, *Trioxys pallidus*. This allowed dusky-veined aphid to become the dominant species in some orchards. Walnut aphids are greenish, much smaller than the dusky veined aphid and typically found scattered on the lower side of the leaf, whereas the dusky-veined aphid feeds in rows along the midvein. Both species overwinter in the egg stage on the tree. After overwintered eggs hatch in early spring, aphids begin feeding on the leaves and reproduce without mating, giving birth to living young. The aphids have many generations in a year and can build up to several hundred per leaf. In addition to the debilitating effect of aphid feeding, heavy infestation can cause almost complete defoliation and sooty mold growing on honeydew can cause severe sunburn on the nuts (UCIPM, 1987). High populations can cause yield reductions of 25%. Aphid honeydew can serve as a food source for *Trichogramma* as well as walnut husk fly.

Monitoring: Both species are monitored by leaf counts. An average of 15 or more aphids per leaf requires treatment (UCIPM, 1987).

Chemical Controls.

Research has shown that economic damage can occur and chemical treatment is warranted if aphid numbers exceed 15 aphids per leaflet (UCIPM, 1987). Diazinon and Cloropyrifos are included in the organophosphate summary in Figure 1.

Endosulfan - PHI not after hullsplit. Applied postbloom by ground at the rate of 2 lb. a.i. per acre (CDPR, 1995). A selective material that does not disrupt biological control of mites and aphids. Preferred material where it can safely be used. Toxic to fish if it drifts into waterways. Typically growers cannot get a permit to use this material.

Oxythioquinox - PHI 30 days. Applied postbloom by ground at the rate of 1.5 lb. a.i. per acre (CDPR, 1995).

Diazinon - PHI 45 days. Applied postbloom by ground at the rate of 2 lb. a.i. per acre (CDPR, 1995). Will help control armored and soft scales if properly timed (UCPMG, 1998). A selective material that is not disruptive to biological control of mites and aphids. Will also control husk fly if properly timed.

Cloropyrifos (see codling moth) will also provide control for aphids.

Alternatives

Growers need to be educated that low levels of aphids can be tolerated since they produce food for *Trichogramma* (Mills, 1998). The key to managing aphids in walnuts is to minimize the use of broad-spectrum materials for codling moth and navel orangeworm, to preserve the walnut aphid parasite *Trioxys pallidus*. This is a key practice in the walnut reduced risk program.

Biological Control

A parasitic wasp, *Trioxys palladus,* was introduced into California in the late 60s and brought walnut aphid populations to low levels. Unless disrupted by pesticides or abnormal weather, this parasite keeps walnut aphids at very low levels. Generalist predators such as ladybird beetles, green lace-wings, earwigs, and minute pirate bugs prey on dusky-veined aphids keeping populations below damaging levels in many situations (UCIPM, 1987).

T. pallidus rarely attacks dusky veined aphid and other parasites are not effective. However generalist predators such as ladybird beetles, green lacewings, earwigs, and minute pirate are efficient regulators of dusky-veined aphid populations. Generally, natural enemies are able to keep populations below damaging levels, but many codling moth treatments are disruptive.

Oil sprays will reduce walnut aphids. These could be used to manage "high populations" of aphids as conventional blocks transition to reduced risk.

Mites:
Twospotted Mite, *Tetranychus urticae*
Pacific Mite, *Tetranychus pacificus*
European Red Mite, *Panonychus ulmi*

Although European red mite can build up to high numbers, it is seldom considered a serious pest. European red mite problems have increased with the increased use of pyrethroids. However, both twospotted and Pacific mites can cause almost complete defoliation, which exposes trees and nuts to sunburn, reduces nut size, and can interfere with harvest. Pacific and twospotted mites overwinter as adult females in the trees or on the orchard floor. Both species are favored by hot, dry conditions and as the weather becomes warmer, they increase in numbers and move throughout the tree (UCIPM, 1987). Severe defoliation early in the season can cause a 25% reduction in yield. As the season progresses, the potential for damage decreases. Webspinning mites are more of a problem in the San Joaquin Valley because of climatic conditions. Pacific mite is the predominant species in the San Joaquin Valley while twospotted mite predominates in the Sacramento Valley (UCIPM, 1987). Miticide uses on walnuts have been summarized from 1990 to 1998 in Figure 5. Omite and dicofol are the two most common miticides used in walnuts. Miticide use appears to follow pyrethroid use (Figure 3). In high pyrethroid years more miticides are used.

Monitoring: Mites are monitored by counting the number of infested leaf clusters. If 10% of the trees monitored contain brown clusters of leaves and predators are not common, a chemical treatment is warranted.

Chemical Controls

Narrow Range Oils - PHI 0 days. Applied postbloom by ground to at the rate of 2 gallons per acre (CDPR, 1995). Must be used with caution because of potential phytotoxicity if trees are stressed or dry (UCPMG, 1998). A selective material that fits well in the IPM program if predator mites are present. Will also suppress aphids.

Propargite - PHI 21 days. Applied postbloom by ground at the rate of 1.8 lb. a.i. per acre (CDPR, 1995). This is the predominant miticide used by walnut growers. Does not disrupt biological control of mites and aphids. Fits well in an IPM program because it is selective. Lower rates can be used to preserve predacious mites. Pacific mite is resistant in the southern San Joaquin Valley.

Fenbutatin-oxide - PHI 14 days. Applied postbloom by ground at the rate of .5 lb. a.i. per acre (CDPR, 1995). Does not disrupt biological control of mites and aphids. Fits well in an IPM program. Does not work well in cool weather. Fenbutatin-oxide use (Figure 5) has decreased in 1998.

Dicofol - PHI 14 days. Applied postbloom by ground at the rate of 1.5 lb. a.i. per acre (CDPR, 1995). Kills predaceous mites. The use of dicofol (Figure 5) has increase in 1997 and 1998.

Chofentezine - PHI 30 days. Applied postbloom by ground to 6% of the acres at the rate of .12 lb. a.i. per acre (CDPR, 1995). Does not disrupt biological control of mites and aphids. Fits well in an IPM program. This chemical only kills eggs and growers tend not to use in because of cost.

Alternatives

Monitoring, using codling moth treatment thresholds, selection of least disruptive codling moth materials, and prevention of stress and dust are all important components of a reduced risk mite management program. Educational programs promoting the use of narrow range oil for mite control are included in the walnut pest management alliance.

Cultural Control Practices

Cultural Controls especially preventing water stress is also currently a key component in managing mites. Stressed trees will not tolerate as many mites as well-irrigated, vigorous trees and are less susceptible to mite damage (UCIPM, 1987). In addition, research on other crops has shown that mite fecundity is increased under water stressed conditions. Minimizing dust by oiling orchard roads and maintaining a well-managed ground cover are important components for managing mites in walnuts.

Biological Controls

Predators are important in keeping mite levels below damaging levels. The most dependable predator is the Western Orchard predator mite, *Metaseiulus occidentalis*, (UCIPM, 1987) which, if not disturbed by some pesticides applied for other pests, can usually keep populations below damaging levels in well-managed orchards. *M. occidentalis* is resistant to most organophosphates and insect growth regulators used for codling moth control, but extremely susceptible to synthetic pyrethroids and carbamates (UCPMG, 1998). Impact of chemicals on predator mites is usually a consideration when choosing chemicals for codling moth. Other important predators include sixspotted thrips, minute pirate bug, and a small beetle, the spider mite destroyer.

Armored Scales:
San Jose Scale, *Quadraspidiotus perniciosus*
Walnut Scale, *Quadraspidiotus juglansregiae*

Scale insects occasionally build up to numbers capable of reducing shoot and nut growth. Large populations may result in the loss of fruiting wood and the production of small-sized walnuts. Scale insects suck plant juices from the inner bark by inserting their mouthparts into twigs and branches. Infested branches stop growing and heavily infested branches and fruit spurs will die. San Jose scale can kill scaffolds. A small, gray shell that makes control difficult covers both species. If the shell covering is removed, the small yellow body of both species can be seen (UCIPM, 1987). Newly hatched nymphs move from under the shell and settle on branches and twigs. The best time to control scale is after hatching until the covering is well developed. San Jose scale has 3-5 generations per year while the walnut scale has 2. Heavy populations may reduce production by as much as 10% if left uncontrolled.

Monitoring: Look for the presence of scales on twigs and branches (UCIPM, 1987). Specific monitoring techniques and treatment thresholds are lacking.

Chemical Control

Because armored scales spend most of their life protected beneath the scale covering, correct timing is important.

Methidathion - 7 day PHI. An organophosphate applied either dormant or postbloom at the rate of 2 lb. a.i. per acre (CDPR, 1995). This material is included in Figure 5, summarizing organophosphate use in walnuts. Will help control codling moth and is disruptive to biological control of mites and aphids (UCPMG, 1998). Must be used with oil or an additive, therefore can be phytotoxic when used during the dormant period.

Diazinon (see aphids) and **Chlorpyrifos** (see codling moth) will help control scale insects.

Alternatives

Armored scales should be control by natural enemies in a reduced-risk program. Timing narrow range oils at susceptible periods could provide supplemental control.

Cultural Controls

Preventing dust that interferes with parasites is an important consideration in scale management. Roads should be oiled or watered regularly and properly managed sod culture to prevent dust.

Biological Controls

Several natural enemies tend to hold armored scale populations in check. Two predaceous beetles, the twice-stabbed ladybird beetle, *Chilocorus orbus* and *Cybocephalus califomicus,* often occur in large numbers and can keep low to moderate populations in check. Two parasitic wasps, an *Aphytus sp.* and *Prospaltella sp.* also help as a barrier to population increase. However once populations are high, these natural enemies may not respond fast enough to prevent damage and sprays are needed (UCIPM, 1987).

Soft Scales:
Frosted Scale, *Parthenolecanium pruinosum*
European Fruit Lecanium, *Parthenolecanium corni*

Soft scales suck plant juices from leaves and twigs. Low to moderate populations are not damaging, but heavy populations reduce terminal growth and vigor interfering with photosynthesis and resulting in smaller nuts and poor kernel quality. Both species have one generation per year, overwintering in the nymphal stage on twigs. In the spring they grow rapidly, become convex in shape, secreting copious amounts of honeydew and the frosted scale secretes a frost-like wax on the cover (UCIPM, 1987). Considered minor pests but can cause up to 10% crop loss if populations are severe.

Monitoring: Examine previous season's growth on randomly selected trees. If more than five nymphs per foot of wood and no parasites are present, a treatment is warranted (UCIPM, 1987).

Chemical Controls

For chemical treatments to be effective, they must be applied in the spring before rapid growth of overwintered nymphs start (UCPMG, 1998).

Methidathion - 7 day PHI. An organophosphate applied either delayed dormant or late summer at the rate of 2 lb. a.i. per acre (CDPR, 1995). This material is included in the organophosphate summary in Figure 5. Will help control codling moth (UCPMG, 1998) and is disruptive to biological control of mites and aphids.

Alternatives

Natural enemies should provide control of soft scales in a reduced-risk program. Petroleum oil applied in dormant or delayed dormant before scale growth begins in the spring is effective, but potential phytotoxicity problems make this treatment risky.

Cultural Controls

Similar to cultural controls for mites and armored scales.

Biological Controls
Several species of parasitic wasps play important roles in regulating soft scale populations. The most important of these are *Coccophagus*, *Encyrtus*, and *Metaphycus Spp.* (UCIPM, 1987). However, parasites seem to cycle and soft scales become widespread every 10 years or so.

Fall Webworm, ***Hyphantria cunea***
Tent Caterpillar, ***Malacosoma californicum***

Larvae of the fall webworm feed inside silken tents skeletonizing leaves reducing photosynthesis and exposing nuts to sunburn. They are pale brown or gray caterpillars with long hairs covering the body. Fall webworms overwinter as pupae and emerge in late summer. There is one generation per year. Infestations are localized and usually are controlled by insecticides applied for other pests (UCIPM, 1987). Heavy populations can almost completely defoliate trees and could cause 20% yield reduction on 5% of the acreage.

Monitoring: Webworms are monitored for their presence by looking for silken tents. Treatments are applied when tents become numerous.

Chemical Control

Insecticides applied for other pests usually control fall webworm. Tents must be wetted thoroughly for insecticide to penetrate.

Diazinon - PHI 45 days. Applied postbloom by ground at the rate of 2 lb. a.i. per acre (CDPR, 1995). This material is included in the organophosphate summary in Figure 5. Will help control armored and soft scales if properly timed (UCPMG, 1998). A selective material that is not disruptive to biological control of mites and aphids.

Phosmet and **Chlorpyrifos** (see codling moth) will also control this pest.

Alternatives

Bacillus thuringiensis - PHI 0 days. Various formulations applied postbloom at label rates by ground when larvae are present (CDPR, 1995). A summary of Bt use on walnuts is in Figure 4.

Cultural Control

Tents can be pruned out on young trees but this is often not practical.

Redhumped Caterpillar, ***Schizura concinna***

Larvae of redhumped caterpillar are yellow with longitudinal reddish and white stripes. The head and fourth abdominal segment are red. They pass the winter as pupae in the soil and there are three generations per year. Larvae feed on leaves and heavy populations can cause severe defoliation resulting in sunburned nuts and small nut size caused by photosynthetic reduction (UCIPM, 1987). Most damaging to young trees, but can cause 5% yield loss if left uncontrolled.

Chemical
This pest is easily controlled by ground or air applications.

Diazinon - PHI 45 days. Applied postbloom by ground at the rate of 2 lb. a.i. per acre (CDPR, 1995). This material is included in the organophosphate summary in Figure 5. Will help control armored and soft scales if properly timed. A selective material that is not disruptive to biological control of mites and aphids.

Phosmet and **Chlorpyrifos** (see codling moth) will also control this pest.

Alternatives

Bacillus thuringiensis sprays at various formulations applied postbloom at label rates by ground when larvae are present (CDPR, 1995). A summary of Bt use on walnuts is in Figure 4. Since codling moth sprays usually control red-humped caterpillar this alternative needs to be promoted in a reduced-risk program.

Biological

Two parasitic wasps, *Hypersoter sp.* and *Apanteles conglomerates,* are important in regulating redhumped caterpillar populations. Generalist predators such as spiders, lacewings, bigeyed bugs, and damsel bugs also prey on larvae (UCIPM, 1987).

WEED CONTROL

In addition to problems at harvest, weeds can cause a multitude of other problems in walnut orchards by reducing the growth of young trees because they compete for water, nutrients, and space. Weeds also increase water use, cause vertebrate and invertebrate and other pest problems, and may enhance the potential for disease. The increasing use of more efficient low-volume irrigation systems has increased the need for selective pre-emergence herbicide use in drip, microsprinkler, and sprinkler-irrigated orchards. Herbicides are generally used only in the tree row. This reduces the total amount of herbicides and prevents the surface roots in the tree row from being damaged by cultivation equipment. Pre-emergence, post-emergence, or a combination of pre- and post-emergent herbicides control weed species. Soil characteristics have an effect on the weed spectrum (often 15-30 species per orchard), the number of cultivations and irrigations required, and the residual activity of herbicides (UCIPM, 1993). Irrigation methods and the amount of irrigation or rainfall affect herbicide selection and the residual control achieved. Herbicide use is summarized in Figure 6 by year from the Pesticide Use Report. Group 1 list would be herbicides reviewed by FQPA for 1999 and Group 2 would be reviewed in 2002. Herbicide use decreased from 1992 through 1996 and begins to increase again after 1997. This increase is primarily due to the increase of Group 2 herbicides.

Monitoring: Treatment decisions and herbicide selections are based on dormant and early summer weed surveys.

Chemical Controls.

Glyphosate -PHI 3 days. Group 2. Applied during the dormant, pre- and/or postbloom by ground one or more times per season at an average rate of .8 lb. a.i. per acre (CDPR, 1995). Nonselective systemic used for a broad range of weed species. Effective anytime on emerged, irrigated, rapidly growing, non-stressed weeds, but activity is slower in lower temperatures. Not effective on some broadleaf weeds at older stages of growth (malva and filaree). Continued use of this material leads to a shift of species and selection of tolerant species. Light activated spray technology has reduced the amount of material applied when weed cover is low by 50 to 80%.

Oxyfluorfen - 0 days PHI. Group 1. Applied by ground one time per season \ at an average rate of 0.27 lb. a.i. per acre (CDPR, 1995). Selective broadleaf herbicide effective as a pre- and post-emergent material. Particularly useful when combined with glyphosate to increase efficacy on various broadleaf weed species and to prevent broadleaf species shifts with Glyphosate.

Simazine -21 day PHI. Group 1. Applied anytime to bare soil or in combination with Glyphosate by ground one time per season at an average rate of 1.3 lb. a.i. per acre. Pre-emergence herbicide of most annual grasses and many broadleaf weeds. Effective when combined with translocated herbicide such as Glyphosate or the contact herbicide Paraquat, and a broadleaf pre-emergence herbicide as in Oxyfluorfen. Typically used for down the row treatment to maintain clean row for irrigation emitters and season long weed suppression.

Diuron -0 days PHI. Group 2. Applied winter through spring by ground one time per season at an average rate of 1.05 lb. a.i. per acre (CDPR, 1995). However, total rate is sometimes split into half with two applications. Pre-emergence used to maintain season long weed suppression down the row. Effective when combined with Simazine, Oxyfluorfen, or Sulfur.

Paraquat - 0 days PHI. Group 1. Applied pre- or postbloom by ground one or more times per season at an average rate of .69 lb. a.i. per acre (CDPR, 1995). Nonselective postemergence material used for quick burndown of most weed species. Less effective against perennials that regrow with vigor such as bermudagrass, dallasgrass, johnsongrass, and bindweed. Most effective when used on early spring or winter growth of annual weed species in combination with pre-emergence herbicides.

2-4-D -60 day PHI. Group 1. Applied as a directed spray postbloom by ground one or two times at the rate of .13 lb. a.i. per acre (CDPR, 1995). Postemergence systemic herbicide selective for most broadleaf annual weeds. Effective on field bindweed. Useful for controlling troublesome perennials when combined with Glyphosate or Fluzifop.

Oryzalin - 0 days PHI. Group1. Applied preemergence by ground one time per season on 5.4% of the acreage at the rate of 1.5 lb. a.i. per season (CDPR, 1995). Pre-emergence selective herbicide most effective on annual grass species and numerous broadleaf annuals. Very safe for young or newly planted trees and on sandy or sandy loam soils. It is used to maintain control in strips down the row. Often used in combination with other pre-emergence herbicides.

Norflurazon -60 days PHI. Group 2. Applied prebloom by ground one time per season on 2.9% of the acreage at the rate of 1 lb. a.i. per acre (CDPR, 1995). Pre-emergence selective herbicide similar to Oryzalin, but is effective on more annual broadleaf and grass species. Can suppress yellow nutsedge or bermudagrass when used year after year. Can cause minor damage to younger trees or those planted on sandy or sandy loam soils. Usually used on new plantings.

Trifluralin -0 days PHI. Group 1. Applied prebloom by ground one time per season at the rate of 1.63 lb. a.i. per acre (CDPR, 1995). Pre-emergence selective herbicide for annual grasses. It must be combined with broadleaf herbicides and incorporated promptly for best results.

Napropamide -0 days PHI. Group 2. Applied prebloom one time per season at the rate of 2.14 lb. a.i. per season (CDPR, 1995). Pre-emergence herbicide effective on annual grasses and several annual broadleaves. Must be applied and incorporated with irrigation or rain within seven days. Very effective in maintaining weed free strips down the row.

Pendimethalin - Non-bearing trees only. Group 1. Applied pre-emergence by ground one time per season at the rate of .5 to 1 lb. a.i. per acre. Effective on annual grasses and some broadleaf weeds. No use data available at this time.

Alternatives

Planting covercrops to improve soil structure, water infiltration and reduce runoff keeping herbicides on site. Proper selection of covercrops and some weeds can provide shelter and food for parasites and predators of pest insects, and reduce dust and hear within the orchard. With proper covercrop selection, it may be possible to supplement nitrogen and reduce commercial fertilizers.

Covercrops and weed culture competes with trees for water and nutrients. With the cost of water increasing, this could be important in some areas. Although it is generally considered that covercrops and weeds are beneficial for mite control, if orchard floor covers suffer water stress, pest mites such as Pacific and twospotted mites will be driven from the cover into the trees. In the absence of sufficient predators, which may or may not follow the pest mites up the tree, mite populations can explode. This is especially true with plants that furnish a bridge from the orchard floor to the trees. Certain leguminous covercrops can also aggravate nematode and gopher problems (McKenry, 1998). All positive and negative attributes of covercrops need to be researched and demonstrated before general recommendations for covercrops in walnuts can be made with confidence. Developing a database to answer these questions would be part of the walnut PMA program.

Reducing the amount of herbicides needed by utilizing the Patchen Selective Spray System that utilizes a risk-assessment system to determine the need for soil sterilants. Using vegetation filter strips at the lower end of the orchard to prevent pesticides from leaving the farm site. Delaying application of soil sterilants until most of the winter rains have fallen to prevent groundwater contamination (Prather, 1998)

Cultural Control Practices

Complete cultivation is an another alternative but requires large expenditure on machinery and is expensive. Machinery used for tilling the soil depends on the use of non-renewable fossil fuels, contributes to air pollution, destroys soil structure, and causes compacted layers in the orchard hindering water penetration. Tillage can contribute to pest buildups by causing dust on trees which increase mite and scale problems, and injure tees allowing disease organisms to invade trees.

Biological Control

There is little biological control of weeds in walnut orchards except for puncturevine weevil that plays an important role, especially around the edges of roadways near orchards. As less toxic, reduced-risk systems are developed, the reliability of puncture vine weevil should increase.

DISEASE CONTROL

Walnut Blight, *Xanthomonas campestris* p.v. *juglandis*

Walnut Blight, a bacterium, is the major disease affecting leaves and nutlets of walnuts. Walnut blight is spread by wind-blown raindrops, sprinkler water, or pollen. The severity of blight each season depends primarily on overwintering populations of the walnut blight pathogen in dormant walnut buds and the presence of free moisture. The bacteria move and infect only when suspended in water. The bacteria survive the winter in dormant buds, catkins, and twig cankers. In early spring, the pathogen enters plant tissue through natural openings infecting leaves, shoots, pistillate flowers, nuts, and catkins. In early season, infected female flowers shrivel and drop from the tree. Later, infected nutlets develop a dark lesion usually at the blossom end; most of these also drop. As nuts mature, lesions can develop anywhere on the husk surface causing kernels to shrivel or darken which renders them unmarketable. These later infected nuts often harbor navel orangeworm. All walnut cultivars are affected, but it is most serious on early blooming cultivars (2,6). If not controlled, yield losses can exceed 50% in wet, warm years. In orchards where copper tolerant bacteria are prevalent and Maneb + zinc is not available or used, 70% yield losses can occur (Buchner, 1998). Bactericide/fungicide use by year has been summarized from the Pesticide Use Reports in Figure 7. Group 1 list would be materials reviewed by FQPA for 1999, Group 2 materials (2002 review) are used so infrequently that they do not appear in the figure. Maneb, which is used for copper resistant blight bacteria, represents Group 1 and all copper compounds used are in Group 3. Figure 7 shows an increase in Maneb from 1994 when copper resistance was found and Maneb received a special local need registration. Bactericide use is related to the amount of spring rains each year.

Chemical Controls

The disease is difficult to control because the bacteria are protected inside dormant buds and catkins. Control of walnut blight is based on spraying copper compounds repeatedly to protect new tissue as it emerges. The number of treatments varies depending on varieties, the length of the rainy season, and history of the orchard.

Copper (Various Formulations). Although air applications are somewhat effective, copper is generally applied by ground because good coverage is necessary. Applied 1-8 (average 2.5) times in the state at the rate of 4 lb. a.i. per acre per application. Resistance to copper is common in the Sacramento Valley and has been found in a few sites in the San Joaquin Valley (UCPMG, 1998).

Maneb - Combined with copper to improve control, primarily in the Sacramento Valley, where copper resistant walnut blight bacteria has been detected. Applied by ground at the rate of 1 lb. a.i. per acre per application. The addition of Maneb + Zinc to fixed copper sprays reduces blight infection by approximately 50% as compared to copper sprays alone. Maneb + Zinc and fixed copper Section 18 registration was obtained from 1994 through 1998. The increase in the use of Maneb can be seen by years in Figure 7. To date, no suitable alternative treatments are available for use on walnuts.

Alternatives

Walnut Blight must still be controlled with copper and copper/Maneb combination sprays. Future strategies may only be able to reduce the number of sprays per season. Bud sampling for copper resistance has been promising in the demonstration project for determining the need for Maneb. Dormant Bud Samples will tell growers the level of inoculum in the block and determine the blight management program for the block. This was tested in the 1999 walnut pma but needs to be repeated in a high rainfall year. Research has shown that silicon penetrators applied delayed dormant can reduce seasonal sprays by fifty percent. Development of a predictive model will help growers determine the need to spray based on weather.

Armillaria Root Rot, *Armillaria mellea*

The severity of this fungus disease depends on the rootstock and the strain of *A. mellea.* The pathogen invades the roots, crown and basal trunk, eventually girdling the crown region and destroying the entire root system causing death of the tree. Symptoms of the disease are creamy white, fan-shaped plaques of fungal mycelia beneath the bark. After rains in the fall or spring, a cluster of mushrooms often appears at the base of infected trees. The fungus develops most rapidly in moist cool soil. It can survive for many years in dead or living roots of many different species of trees. Generally, clusters of trees may be infected at one or several sites in the orchard (UCIPM, 1987). A localized problem but can cause 25% yield loss in infected orchards.

Chemical Controls

Methyl Bromide has shown some promise for control of *A. mellea* at the rate of 300-600 lb. per acre applied by injection with tarping. It is recommended that a deep-rooted covercrop be grown on the soil to dry it out completely before treating. Even under these conditions, eradication is difficult and this material is not widely used for *A. mellea (6).*

Cultural Controls

Choice of rootstock is important in managing *A. mellea.* Northern California black walnut rootstock and Paradox hybrid are considered resistant, but in recent years have been infected in some areas. If the use of methyl bromide fumigation is suspended, infection of these rootstocks is expected to increase. English or Persian walnut rootstock is very susceptible to *A. mellea* and should not be planted where *A. mellea* is a problem.

Alternatives

Remove infected and adjacent trees to slow down spread. Avoid planting on a site infested with *A. mella.*

Crown Gall, *Agrobactefium tumefaciens*

Although crown gall can affect established orchards, the disease is most damaging to young trees. If left unchecked, crown gall may progress around the crown weakening and eventually girdling the tree. Young galls are smooth; as they age, they become rough and increase in size.

Old galls are dark, brittle and cracked. The pathogen usually infects through wounds and young trees in nurseries are particularly prone to infection because of the many potential injuries during rearing and digging (UCIPM, 1987). If left uncontrolled and trees become stunted, losses of 50% can occur. Grown gall has become an increasing problem in developing new orchards.

Chemical Controls

Gallex™ is used to selectively kill tumors on individual trees in existing orchards. The treatment is most effective when used on trees 4 years old or less. This procedure is expensive and difficult to carry out (UCPMG, 1998).

Alternatives

The best management practice for this disease is prevention.

Biological Controls

Agrobacterium radiobacter-84 is a biological control agent used as a spray or dip on 85% of nursery trees after digging and before planting in the field (UCDANR, 1998).

Cultural Controls

Black walnut is much more tolerant than Paradox hybrid, although neither is totally resistant. Avoid excessive root injury in young trees or during cultivation (UCIPM, 1987).

<u>Phytophthora Root and Crown Rot,</u> *Phytophthora spp.*

About 10 different *Phytophthora* species attack walnut trees. The pathogen enters the tree either at the crown near the soil line, at the major roots or at the feeder roots, depending on the species. Trees affected with *Phytophthora* first show small leaves, sparse foliage, and lack of terminal growth. Infected trees may decline for several years or die within the same growing season in which the foliage symptoms first appear. *Phytophthora* can survive in the soil for many years and spreads and infects the trees during moist cool to moderate temperatures in spring and fall, and some infection may occur in the summer depending on species (UCIPM, 1987). A localized problem that affects 20% of the orchards. Yield losses of 50% can occur in infected orchards.

Chemical Controls

Metalaxyl - Applied to the soil as a drench. This material was included in Figure 7 as a Group 2 material; no group 2 uses were reported. It has little use in walnuts and effectiveness is limited to small trees.

Alternatives

Moisture monitoring is extremely important to avoid over irrigating and saturated soils thus increasing the incidence of Phytophthora. In addition, this practice will decrease the amount of nitrogen moving into groundwater and lessen the chances of runoff of toxicants into streams.

Cultural Control Practices

Rootstocks vary in susceptibility to the different *Phytophthora* species; none are resistant to all species. In general, Paradox rootstock is more tolerant than northern California black walnut. Plant on soil with good surface and internal drainage. Plant on ridges to keep standing water from around the base of the trees and manage irrigation to minimize soil saturation (UCIPM, 1987).

CHALLENGES TO IMPLEMENTING CHANGE

The primary barrier to adoption of reduced-risk management programs is that chemical-based programs are cheap and effective. Growers perceive that reduced-risk programs are more expensive and a higher risk to them. The first year walnut pest management program showed that codling moth damage was higher 3.0% in the reduced-risk programs than 1.2% in the grower standards. Also, the costs to the grower of the reduced-risk programs averaged $96.12 higher per acre than the grower standards. The walnut pest management alliance has decided to focus on the orchards that reduced-risk practices showed the greatest success for the 2000 demonstration project.

Another barrier for adoption, as with many other components of the reduced-risk program, is convincing growers of the value of increased monitoring and convincing them to pay for this level of expertise. In addition there is a shortage of consultants or scouts interested in conducting increased monitoring (Aulakh,1998).

There are also barriers to growers using covercrops. These include the challenge of planting covercrops in a walnut orchard such as the short planting time between harvest and leaf fall. The large walnut leaves will inhibit growth of the covercrop during the winter.

INNOVATION

Mating Disruption was proven to work in walnuts in the early nineties. However, the cost of the material and the labor to get it into the large tree canopy was cost prohibitive. Estimated costs were $300 for material and $700 for labor on pruning towers to make the application. The walnut PMA is going to look at the successes in apples and pears with mating disruption. New commercial pheromone technology has been developed for these crops that only need to be applied once per season. The greatest successes in the 1999 PMA were from the use of these commercially available dispensers. Growers with high codling moth population orchards may have to supplement mating disruption with organophosphates to reduce the population ensuring success with these products. This is the goal of the 2000 walnut PMA to demonstrate this strategy so that walnut growers can successfully use mating disruption.

An emerging technology of using pheromone in a paraffin base marketed by Agrium was not successful in the 1999 walnut PMA. More development work needs to be done on formulation and application before it will be readily adopted by the walnut industry. Research using "puffers" to dispense pheromone in walnuts was unsuccessful in 1998. Walnut growers using this method suffered 18-20% damage. The puffers suffer from mechanical difficulties and more research needs to be conducted before it is known that the entire walnut canopy in a block is permeated with sufficient pheromone levels to keep codling moth in control. More research started in 1999 on understanding the puff plume is being conducted by Dr. Steve Welter. This research is necessary before this technology can be successfully used. Results will be incorporated into the walnut PMA when it is developed.

Dr. Nick Mills, UCB, is also working on a long-term solution with plant breeders to find characteristics that may make cultivars less susceptible by selecting for late blooming and finding characteristics that keep larvae in husks. This information of codling moth preferences for varieties by generations can be used in developing codling moth management programs in the walnut PMA (Mills, 1998).

It is well known that orchards utilizing covercrops and native vegetation require more water and possibly fertilizer than clean tilled orchards. Up to now it has not been documented just how much extra additional water and fertilizers are needed. A key management practice to be incorporated into the walnut PMA by Dr. Terry Prichard is water and nutrition management in conjunction with non-tillage.

REFERENCES

Aulakh,Karminder. 1998. CAFF Davis, BIOS walnut project Coordinator. Personal Communication, Apr. 30, 1988.

Buchner, R.B. and W.H. Olson, C. Gilles, N. Shawareb. 1998. Walnut Blight Control Investigations. In: Walnut Research Reports 1998. P. 327-337.

California Department of Pesticide Regulation. 1995 Annual Pesticide Use Report.

Hasey, Janine and C. Christofferson. 1997. Codling Moth Control with Imidan and Effects on Beneficial Insects. In: Walnut Research Reports. P. 415-421.

Integrated Pest Management for Walnuts (Second Ed.) 1987. University of California Statewide Integrated Pest Management Project, Division of Agriculture and Natural Resources. Publication 3270.

McKenry, Mike. 1998. Nematology Specialist, University of California, Kearney Agr. Center, Personal Communication. Feb. 18, 1998.

Mills, N.J. 1998. Importing Parasitoids for Areawide Management and Trichogramma for Local Management of codling Moth in Walnuts. In: Walnut Research Reports 1998. P. 169-178.

Olson, W.H. and C. Pickel, S. Opp. 1997. Training on the Biology, Monitoring and Control of Walnut Husk Fly. In: Walnut Research Reports 1998. P. 197-199.

Olson, W.H. 1998. U.C. Cooperative Extension Farm Advisor, Butte County, Personal Communication. Feb. 18, 1998.

Pickel, C. and W. Bentley, N. Mills, W. Olson, R. Buchner, N. Darby, and L. Martin. 1998. Investigations of Long-Term Codling Moth Management in Walnuts. In: Walnut Research Reports 1998. P. 159-168.

Sample Costs to Establish a Walnut Orchard and Produce Walnuts. 1997. Southern San Joaquin Valley. U.C. Cooperative Extension.

U.C. Pest Management Guidelines. Walnut. University of California, Statewide Integrated Pest Management Project. 1998.

VanSteenwyck, R.A. and S.C. Welter 1998. Evaluation of Codling Moth Resistance to Guthion and Lorsban. In: Walnut Research Reports 1998. P. 415-421.

Walnut Production Manual. University of California, Division of Agriculture and Natural Resources. 1998. Publication 3373.